GENERAL DYNAMICS
Armament Systems

Derivation of a Pressure Limit for the M61 Family of Guns

Jim Talley

Systems Weaponization Engineering
General Dynamics Armament Systems
Burlington, Vermont USA

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The M61 Family of Guns

The M61 History
Project Vulcan: 1949 - 1959

The Pressure Definition Problem

- **The M61 was designed before sophisticated analytical techniques were common.**

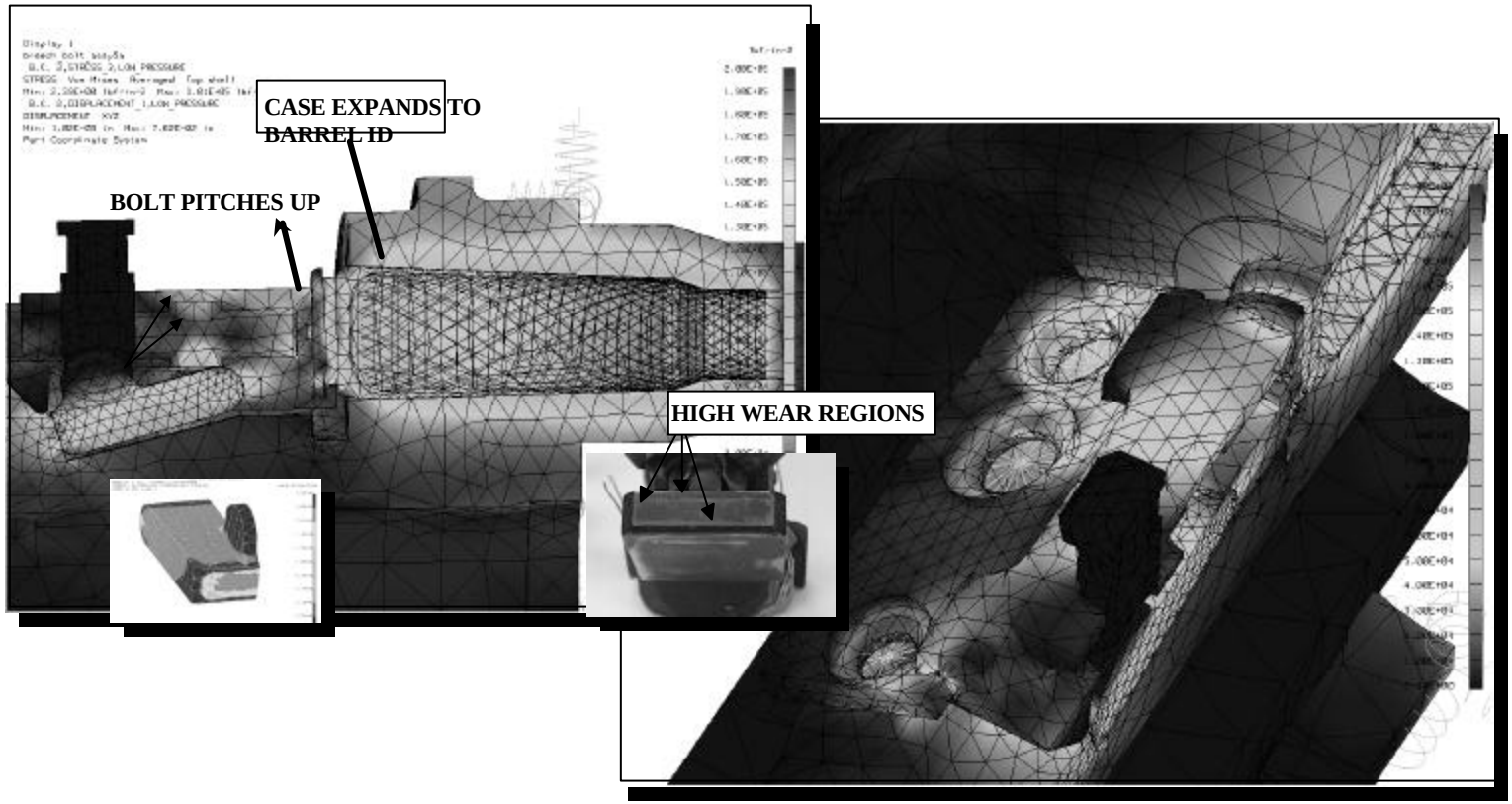
- **Ammunition pressure measurement technology from the 1930s & 40s did not provide an accurate peak chamber pressure for minor caliber gun design.**

The 'Model C' Gatling Gun Predecessor to the M61

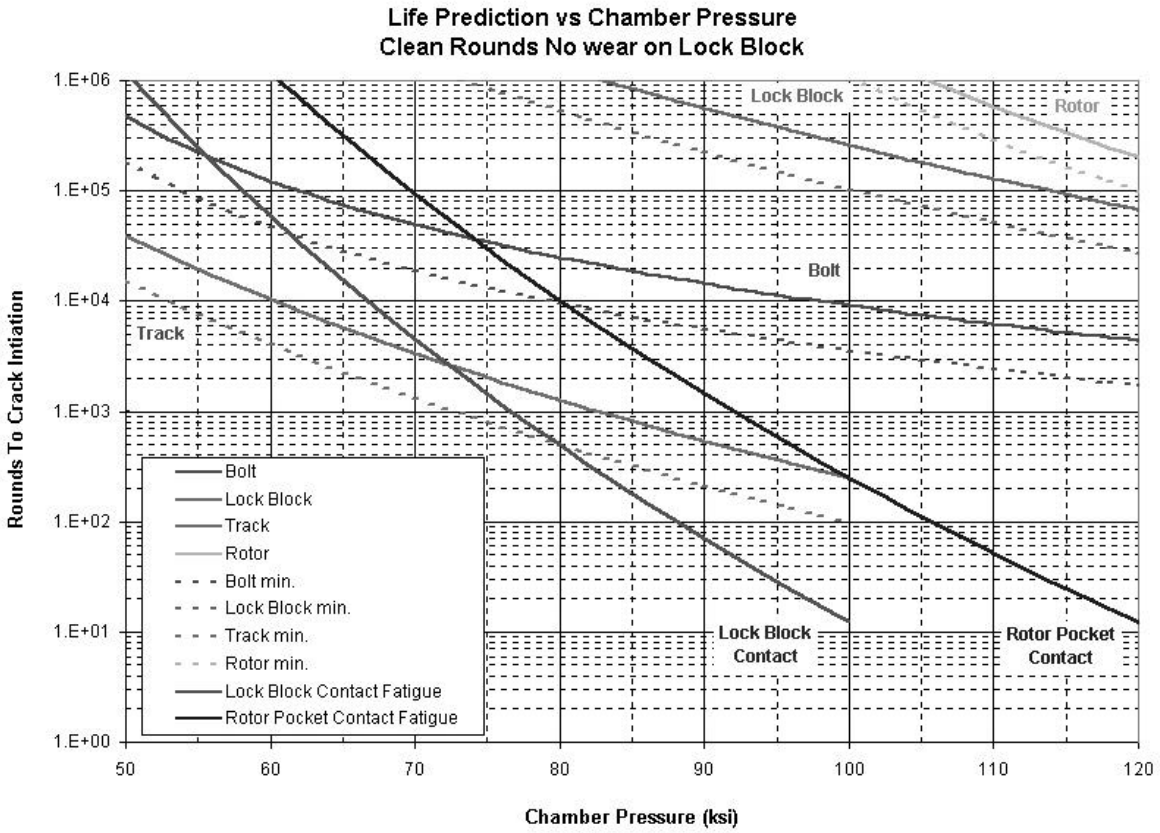
The M61 Reverse Engineering Program

- **Detailed experimental and analytical look at the M61.**
- **USAF-funded through a USN contract vehicle.**
- **First comprehensive look at the M61 in 30 years.**

M61 Vulcan Firing Loads



M61 Parts Life vs. Peak Chamber Pressure Relationships

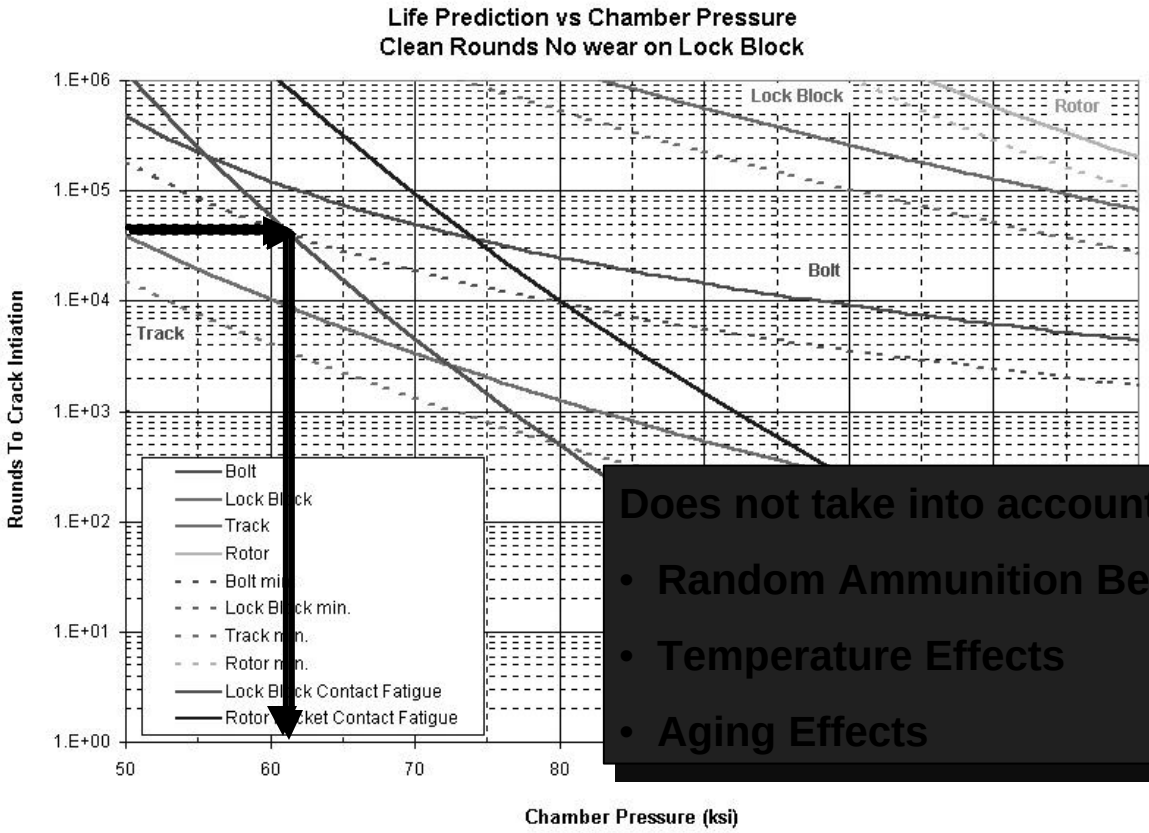


The Next Step

- **With the results of the M61 Reverse Engineering Study, we can finally generate a methodology to answer the question:**

What Peak Pressure Can the M61 Tolerate ?

The Incorrect Way...



Does not take into account:

- **Random Ammunition Behavior**
- **Temperature Effects**
- **Aging Effects**

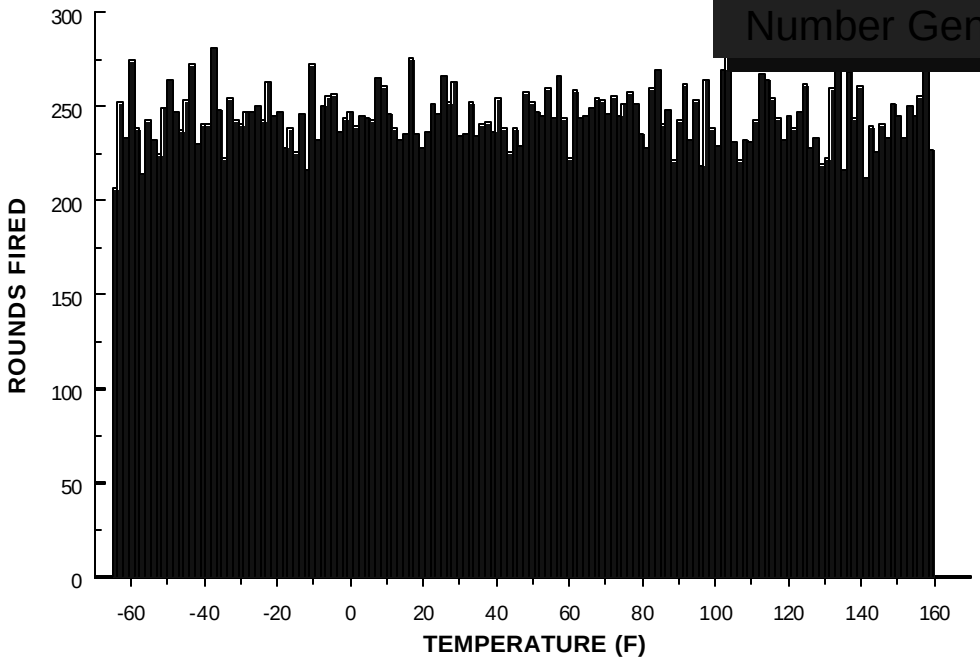
The Correct Way

- **Assume a known distribution of pressures & temperatures are fired.**
- **Assess the damage caused by each round.**
- **Estimate the number of rounds to failure.**

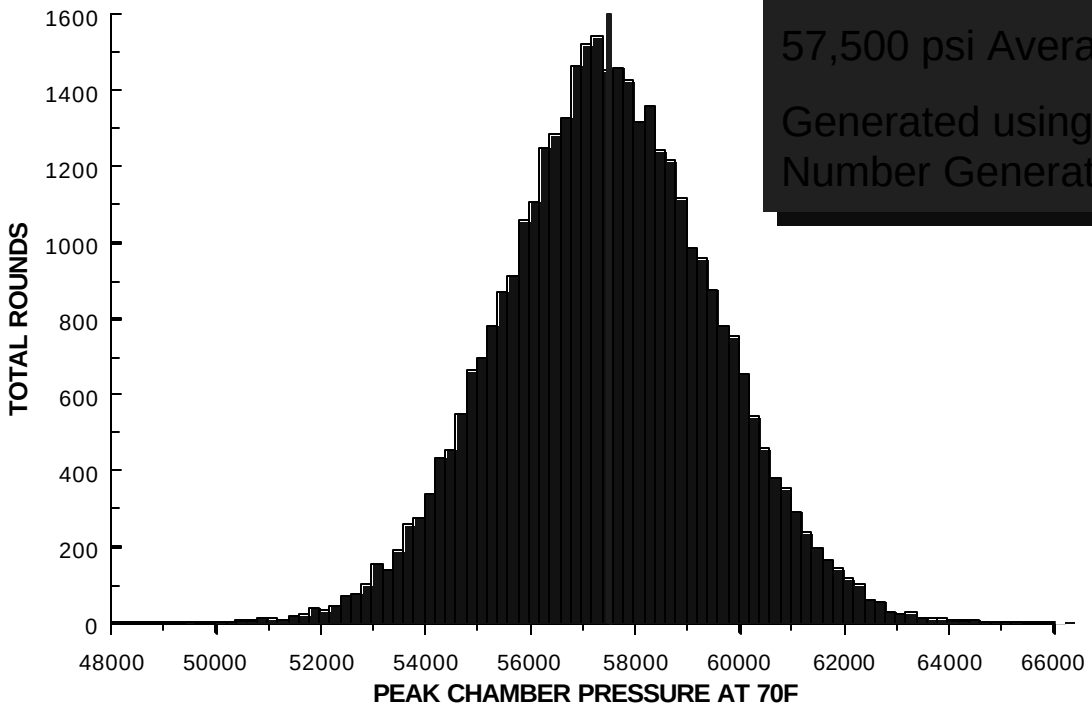
Step 1: Assume a Temperature Distribution

36,000 Rounds between -65ºF & 160ºF

Generated using a Uniform Random Number Generator



Step 2: Assume a Pressure Distribution

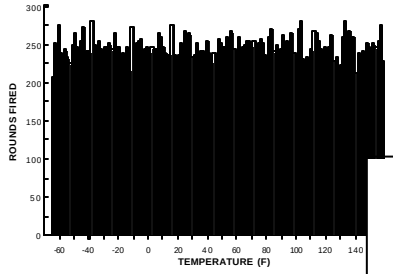


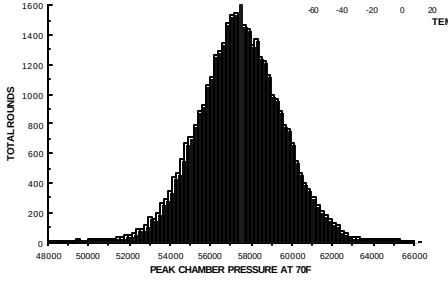
36,000 Rounds

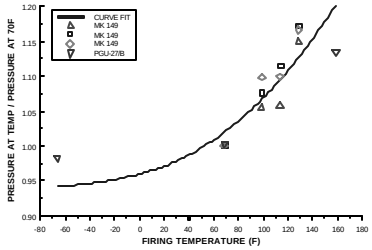
57,500 psi Average / 2,000 psi s

Generated using a Gaussian Random Number Generator

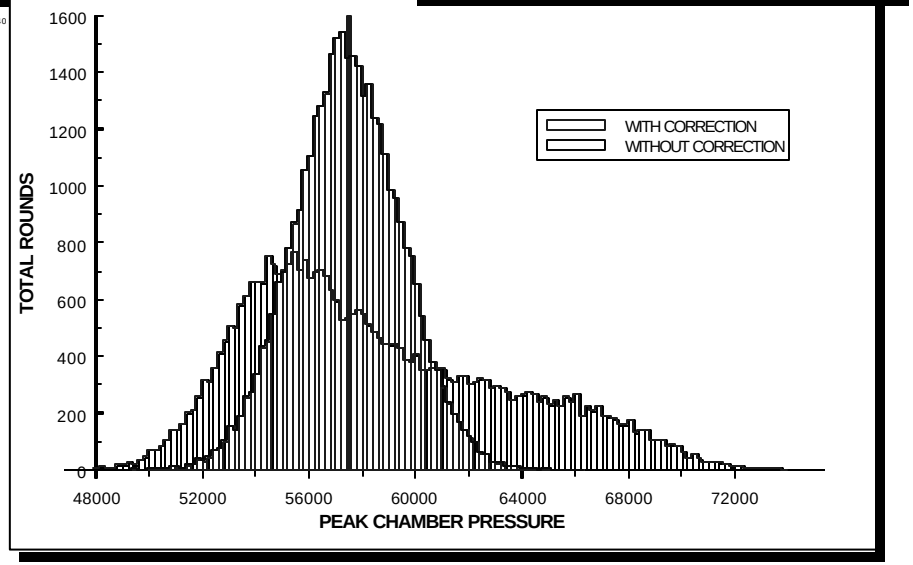
Step 3: Correct the Pressures for Temperature Effects







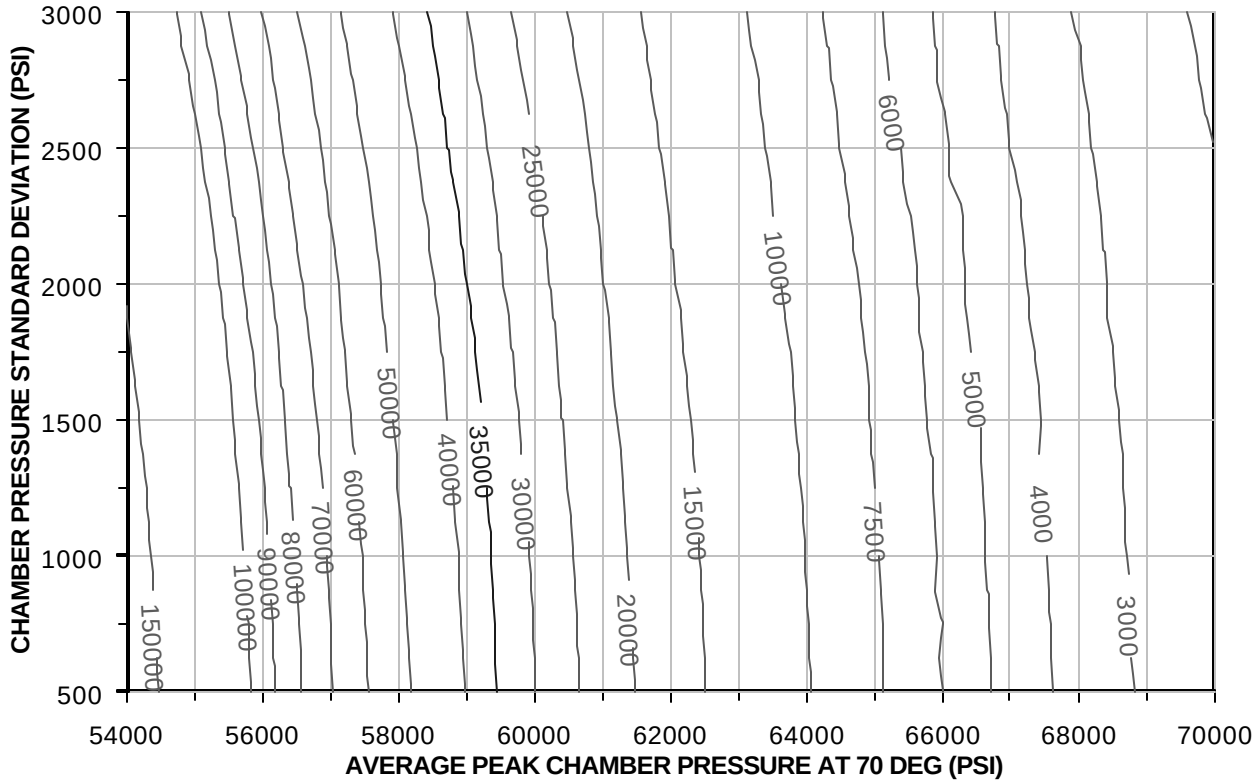
36,000 Rounds, between -65°F and +160°F



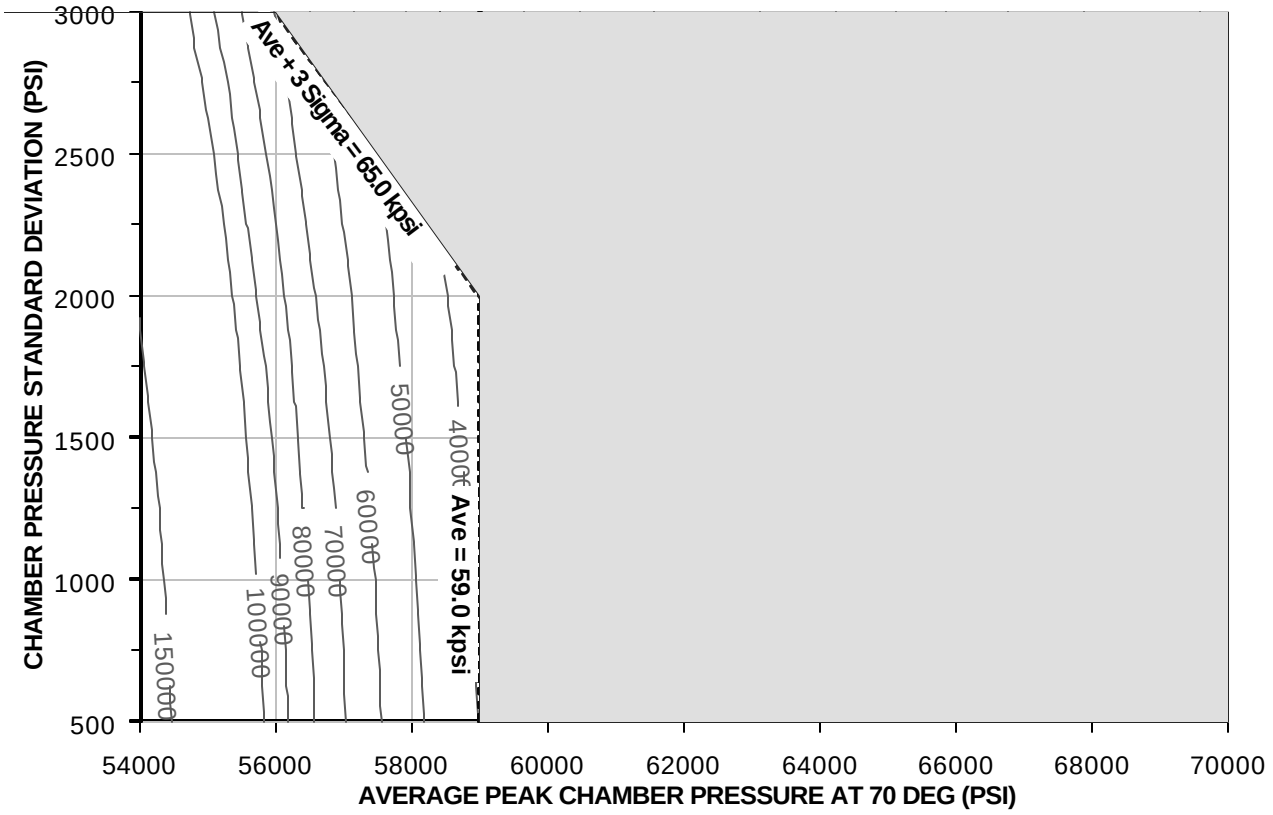
Step 4: Assess the Gun Damage

- Mean pressure varied from 54,000 to 70,000 psi at 70ºF
- Standard Deviation varied from 500 to 3,000 psi.
- Even temperature distribution from -65 to +160°F.
- Miner's Rule applied until failure is predicted.

Step 5: Map the Predicted MRBF Results For No Maintenance



Step 6: Set the Limits to Maintain a Desired Maintenance Interval



Summary Points

- **Ammunition pressure limits are gun constraints and belong to the weapon.**
- **Analysis can be used as a basis to estimate the structural response of the weapon to varying ammunition behavior.**
- **Realistic ammunition pressure limits can be derived that take into account:**
  - ➢ **Random ammunition effects**
  - ➢ **Temperature effects**
  - ➢ **Effects of aging**